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Small Racetrack – Design, Mechanical Analysis and Fabrication

Srinivas Bhashyam

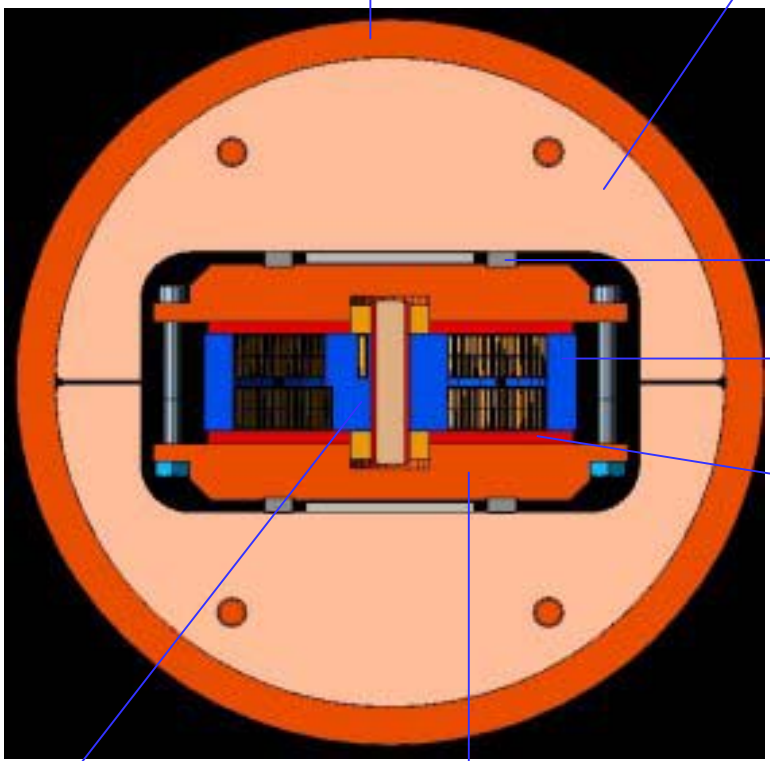
Outline

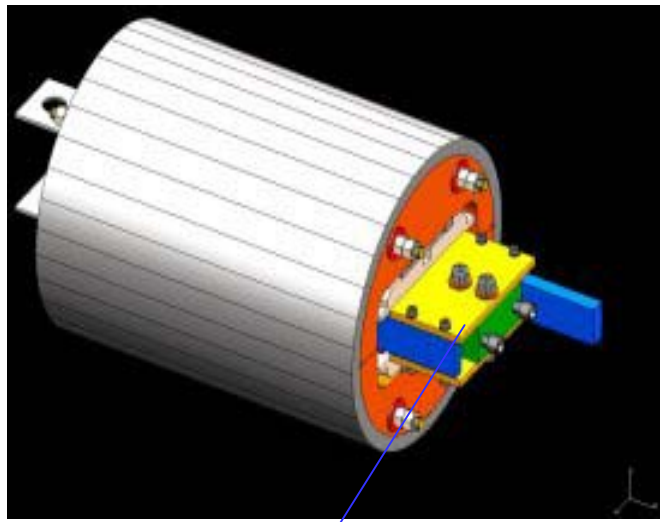
- **Design Overview**
  - **Mechanical Structure**
  - **Winding Assembly**
  - **Tooling**
- **Magnetic/Mechanical Analysis Summary**
  - **Design Criteria**
  - **Shell Stresses/Strains**
  - **Coil Stresses/Displacements**
- **Fabrication**
  - **Procurement Status**
  - **Fabrication scenarios and schedule**

Design Overview

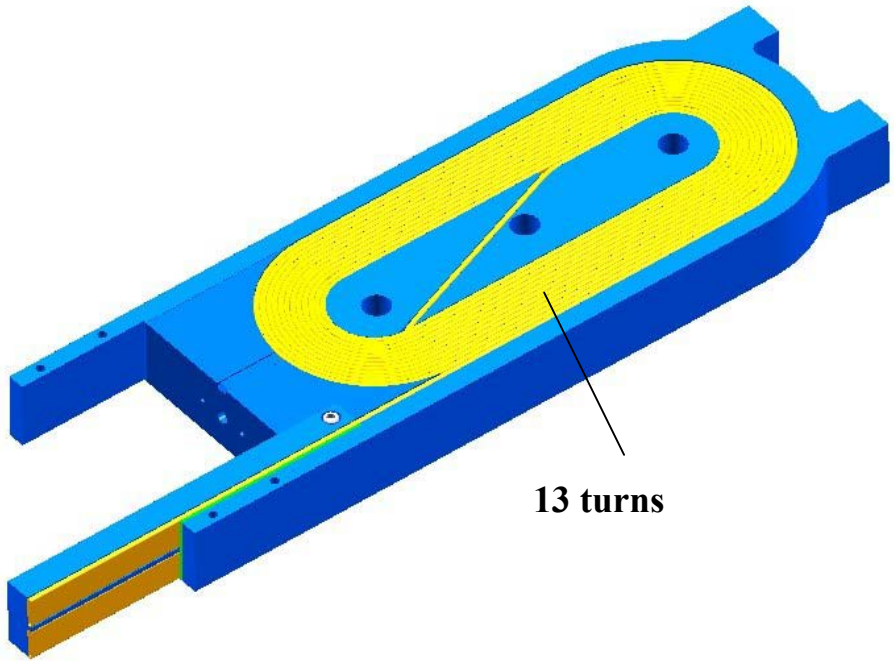
- **Mechanical Structure**
  - Yoke, skin, pressure pad, keys – identical to LBL design
  - Steel skin thickness – scaled to 3.99 mm (LBL design 1.35 mm) to compensate for difference in thickness of coil package – FNAL single coil package, LBL two coil package
  - End support parts – scaled to FNAL cable width
- **Winding Assembly**
  - Wider cable – FNAL cos(θ) cable
  - Double layer design (no interlayer splice) – 13 turns
  - Modified pole piece
  - Horseshoe, end shoe scaled to FNAL cable width
  - Leads on the same side
- **Tooling**
  - Reaction, impregnation tooling parts scaled to FNAL cable width (where appropriate)

Design Overview – Mechanical Structure





Design Overview – Winding Assembly

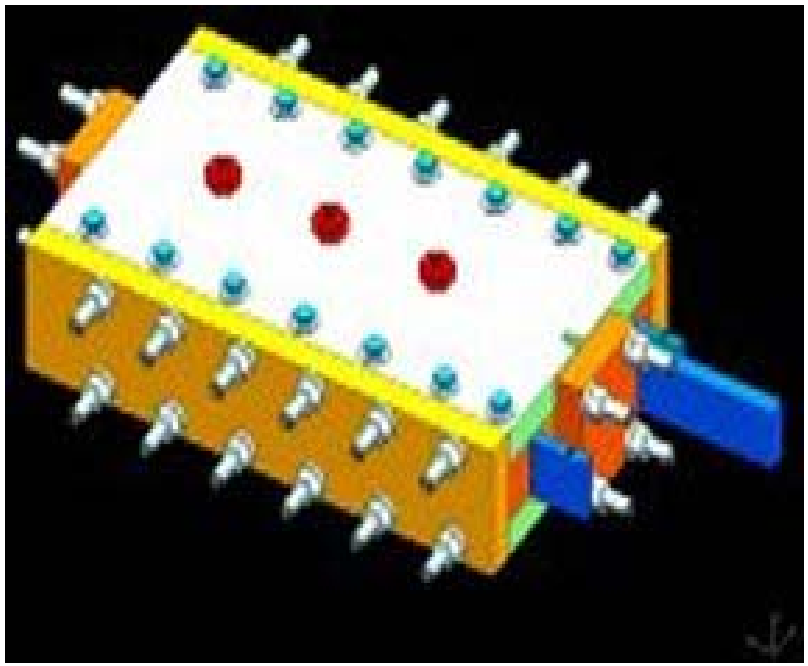


13 turns

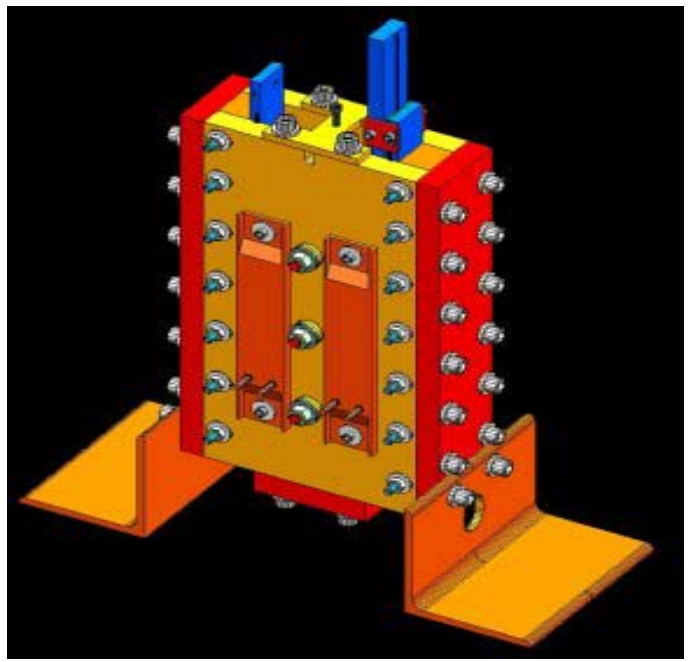
R = 18.6 mm

R = 17.3 mm

Design Overview – Tooling

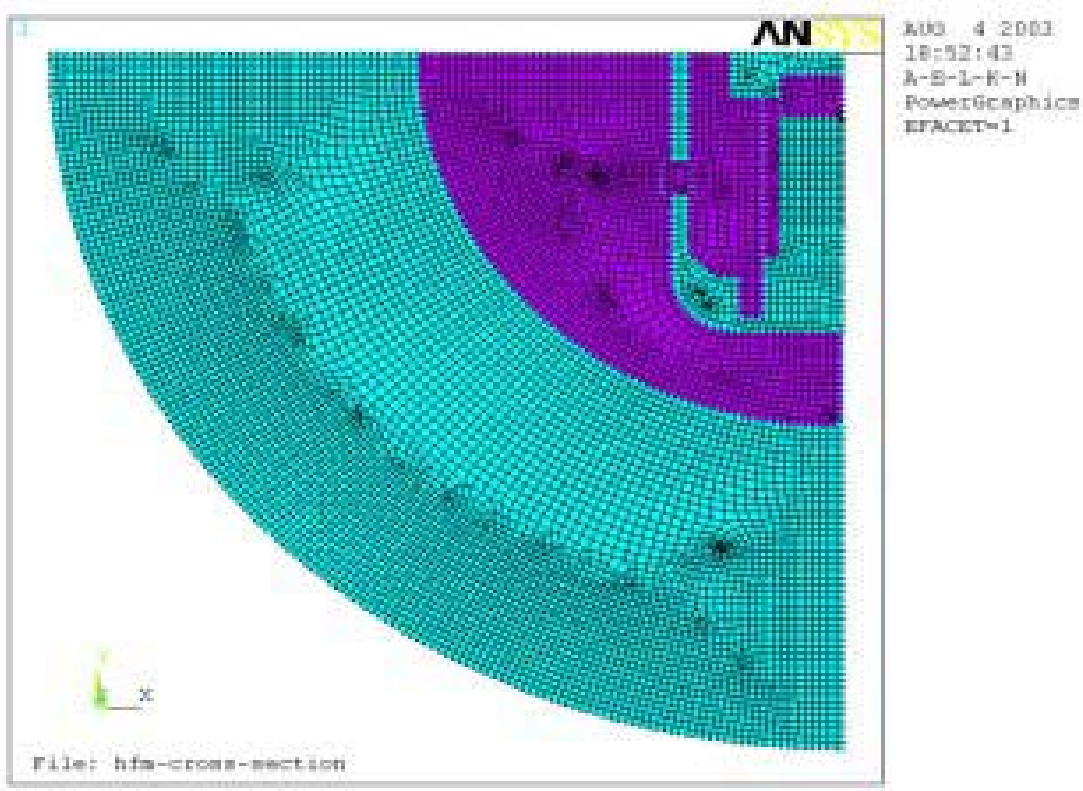


Reaction Fixture



Impregnation Fixture

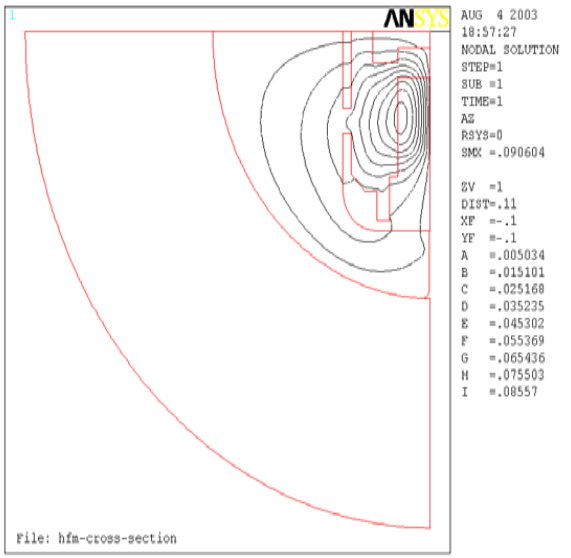
Magnetic Analysis

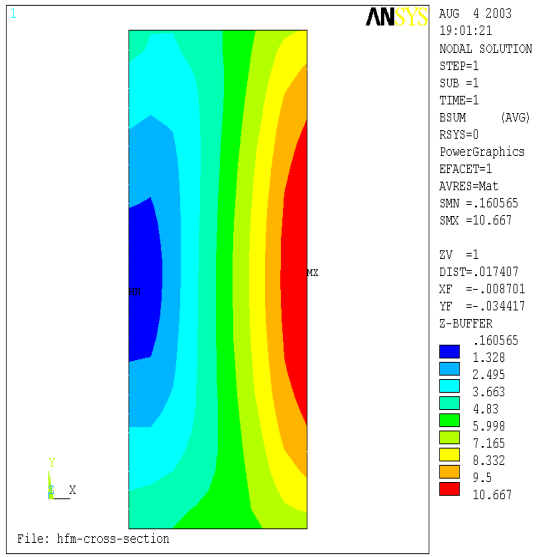


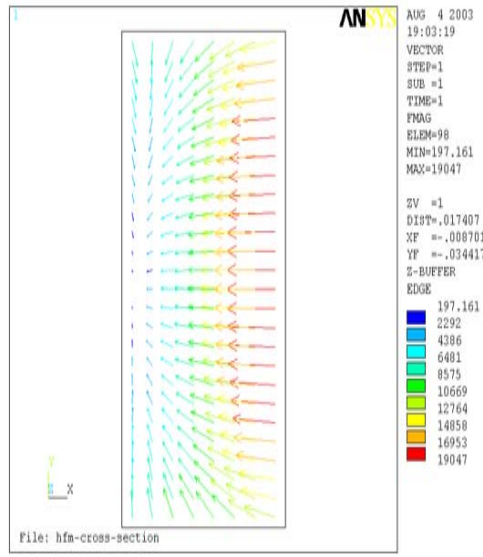
All parts in purple represent iron – saturation effects included

Magnetic Analysis

I = 28 kA







- Peak field = 10.7 T
- Total coil separation force ≈ 850 kN
- Peak field based on roxie = 11.2 T, coil separation force = 750 kN (Vadim Kashikin)

Mechanical Analysis – Design Criteria and Specifications

- No coil separation allowed @ I_{max} = 28 kA (Reacted Nb_3Sn cable in the transition region from the top layer to the bottom layer)
  - Coil remains under compression @ 4.2 K, I_{max} = 28 kA
- Maximum shell stress during bladder operation < yield stress of 6061 T6 Aluminum = 250 MPa
- Maximum coil stresses during assembly and cool-down < 150 MPa
- Key/yoke interference = 0.5 mm
- Bladder pressure required for inserting keys = 60 MPa
- Minimum friction between yoke and skin to reduce shell stresses during bladder operation
- Shell stresses monitored using strain gages

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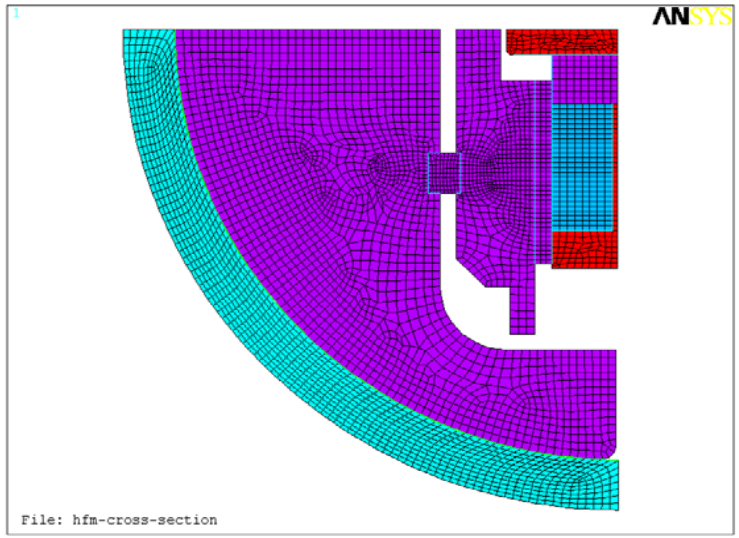
Mechanical Analysis – ANSYS Model and Material Properties



Material	Modulus (GPa)		Poisson's Ratio	Integrated Thermal Contraction (mm/m)
	4.2 K	300 K		
6061 Aluminum	80	70	0.3	4.35
1018 Steel	225	210	0.3	2.07
304 Steel	225	210	0.3	3.02
Coil	35	35	0.3	3.58
G-10	14	14	0.3	7.62

- Surface-surface contact elements ($\mu = 0.15$)
- $\mu = 0$ contact elements between shell and yoke

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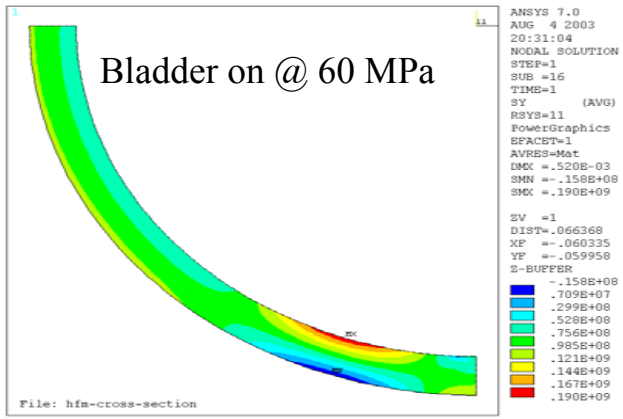
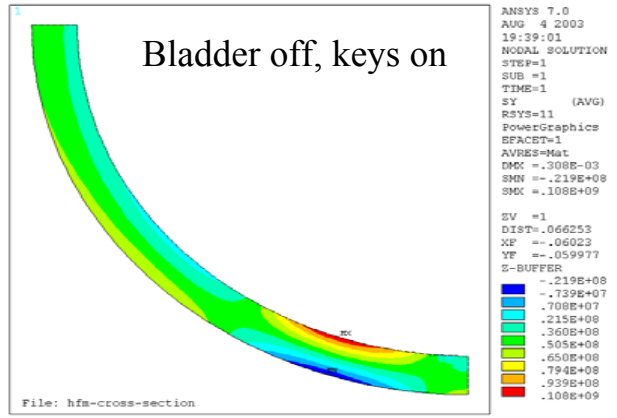
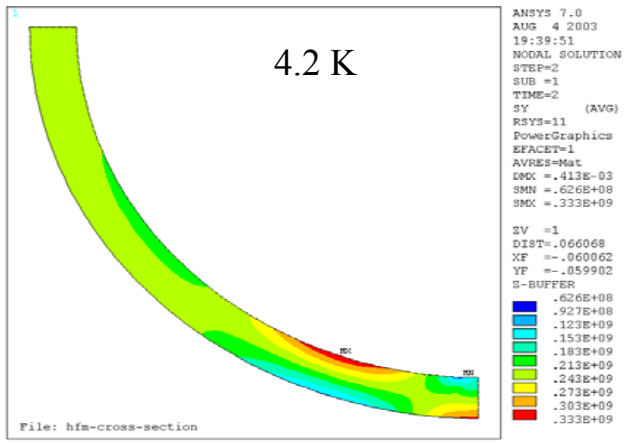
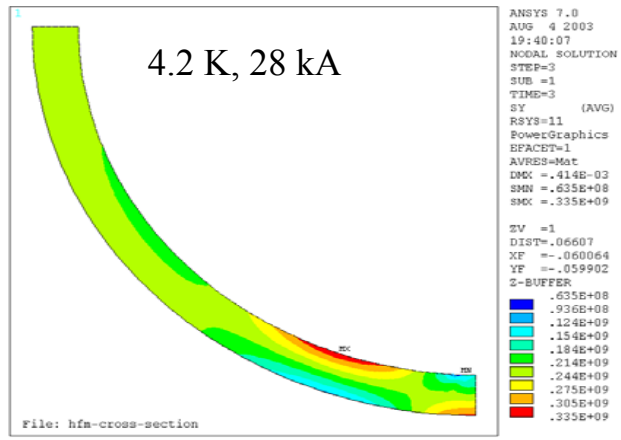
Mechanical Analysis – Azimuthal Shell Stresses









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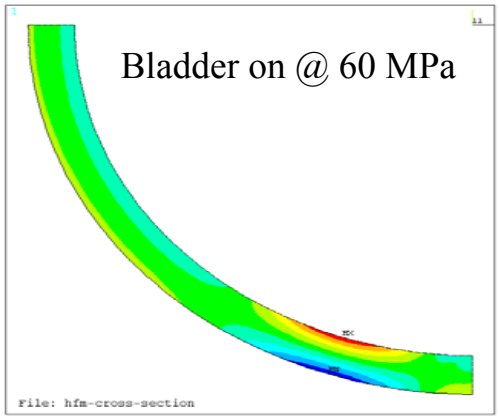
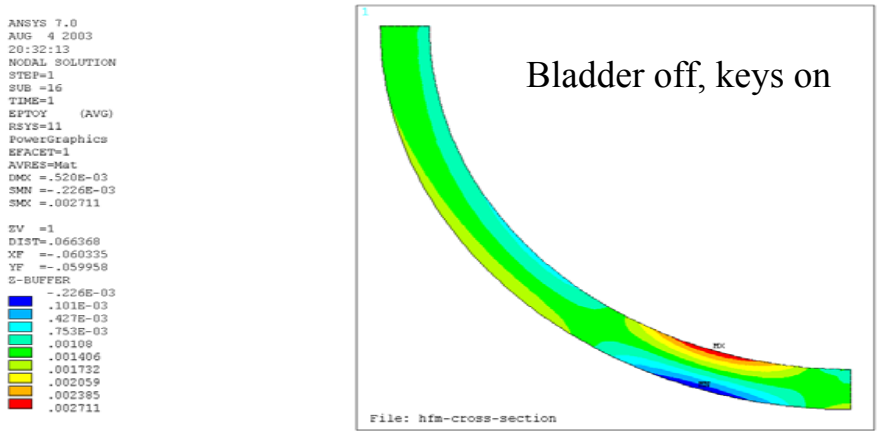
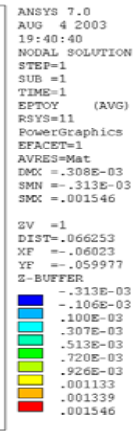
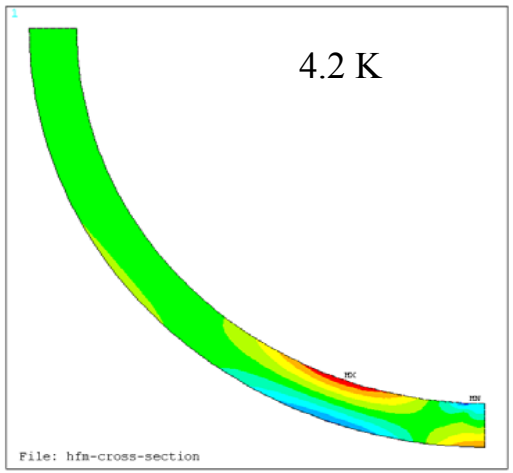
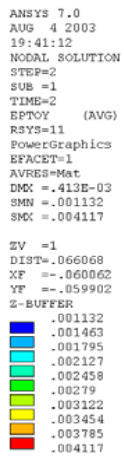
Mechanical Analysis – Azimuthal Shell Strains

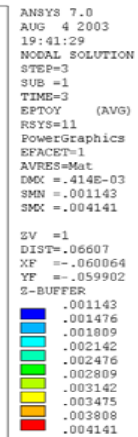












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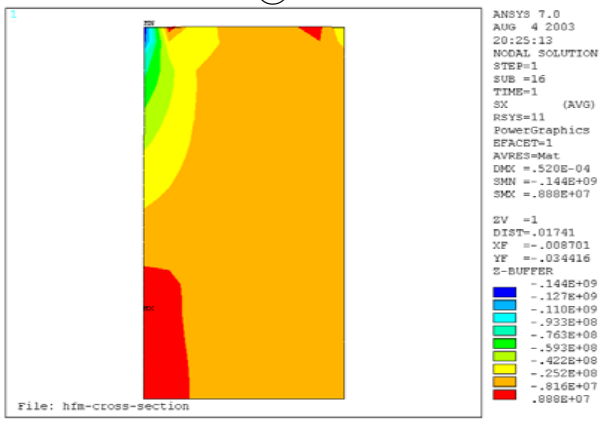
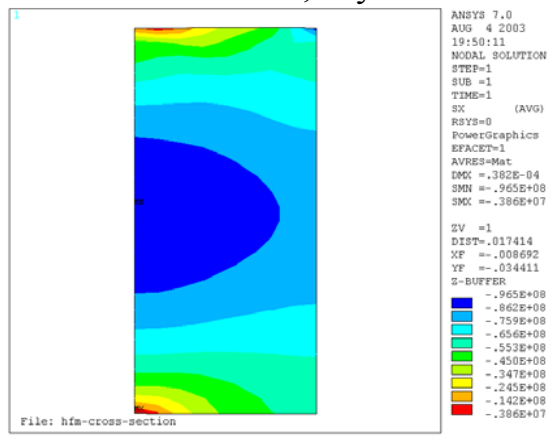
Mechanical Analysis – Radial (S_x) Coil Stresses

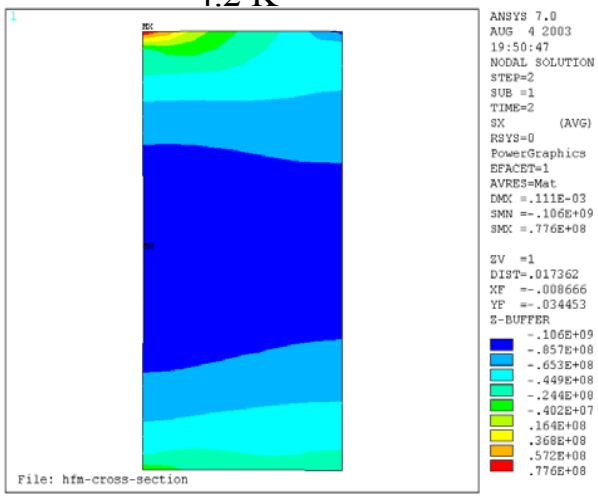
Bladder on @ 60 MPa



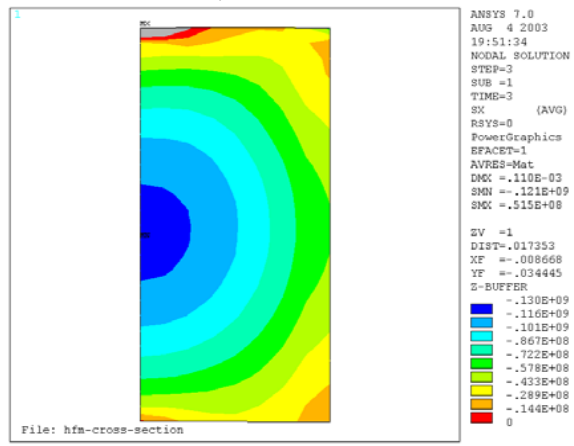
Bladder off, keys on



4.2 K



4.2 K, 28 kA



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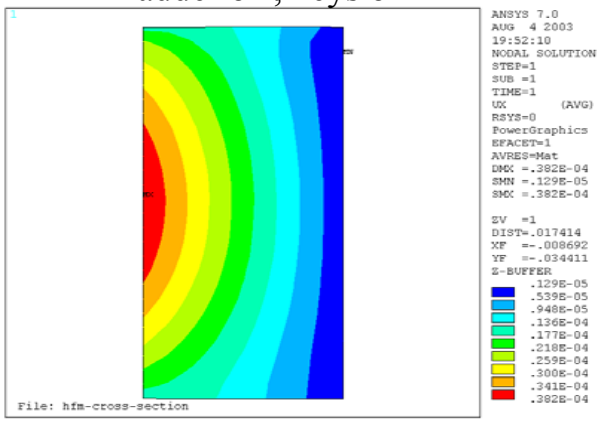
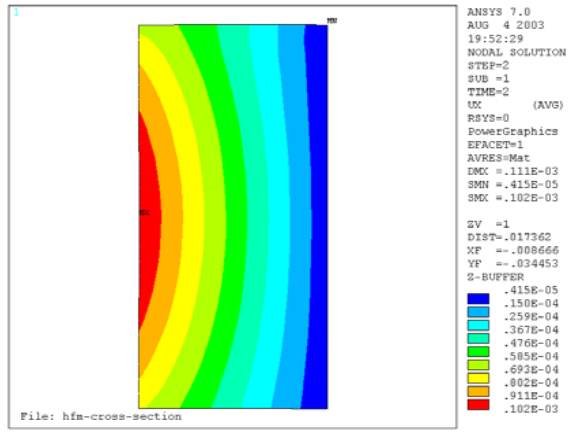
Mechanical Analysis – Radial (U_x) Coil Displacements

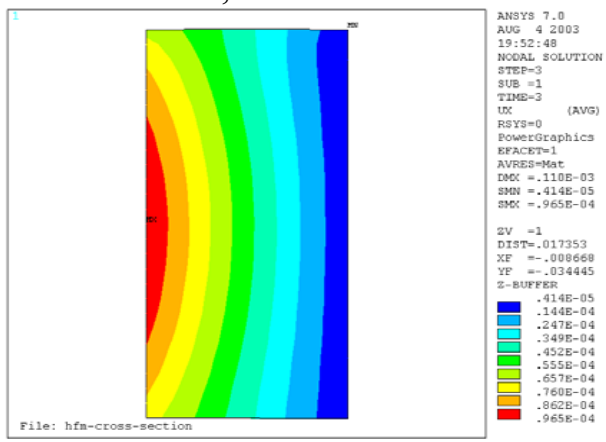
Bladder off, keys on



4.2 K



4.2 K, 28 kA



Fabrication – Procurement Status

Description	Design Modifications/ Drawings Release	Procurement	Expected Final Delivery Date	No. of sets
coil winding assembly	**completed**	**Parts in QC**	**Aug 15,2003**	**2**
mechanical structure	**completed**	**Parts in QC**	**Aug 15,2003**	**2**
Tooling – Reaction/Impregnation	**completed**	**Requisition initiated**	**Sept 15 ,2003**	**2**

Fabrication – Schedule

Fabrication – Schedule

Summary

- Design changes have been kept to a minimum
- Modifications are being validated using FEA
- Fabrication process has to follow LBL procedures as closely as possible (including the subtle steps)
- Strong collaboration between FNAL and LBL essential for successful execution of the first small racetrack model magnet